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THE APPROXIMATE MELTING POINTS OF SOME COMMERCIAL COPPER ALLOYS

BY

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THE APPROXIMATE MELTING POINTS OF SOME COMMERCIAL COPPER ALLOYS.

By H. W. Gillett and A. B. Norton.

INTRODUCTION.

The Bureau of Mines has undertaken an investigation of the nonferrous-alloy industry in the United States with especial reference to the development of more efficient methods of melting brass and other alloys, the saving of metal losses, and the prevention of occupational diseases among foundry workmen. The results of an investigation of current melting practice in brass foundries will be given at length in a bulletin now in course of publication.

In the course of the study of metal losses, and the possible development of more efficient types of melting furnaces, it became necessary to determine with approximate exactness the relation between the pouring temperatures and melting points of various copper alloys. The results of these melting-point determinations are put on record in this paper in order that the information may be available to all persons interested in the manufacture of such alloys or in related metallurgical problems.

The binary systems of copper-tin and copper-zinc alloys have been thoroughly studied not only as regards melting points, but as regards the full phase-rule relationships showing the different phases present in the solid alloys at different temperatures, and also as regards tensile strength. The Alloys Research Board, under Thurston, studied the mechanical properties of the ternary system of copper-zinc-tin alloys in detail, but as pyrometers were not perfected at the time of that investigation the temperature determinations were confined to crude determinations of the pouring temperatures of the two binary—copper-tin and copper-zinc—systems, and were made by pouring the molten alloy into water, measuring the rise in temperature of the water and figuring the pouring temperature from the assumed specific heat of the alloy. The method, though the only one available at the time, was so crude and subject to so many errors that the results are of little or no value. Experiments on the copper-zinc-tin system with reference to the phase rule are in progress at Cornell University, but no melting-point determinations have yet been made.

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Thus, while the melting points of the two binary systems are well known, those of the commercial casting alloys that contain copper, zinc, tin, and lead, or copper with two of the other components, have received little or no study.

LACK OF DATA ON THE POURING TEMPERATURES OF TERNARY AND QUATERNARY ALLOYS.

Few figures on the melting points of ternary and quarternary alloys can be found in the literature on alloys.

Primrose [a] mentions pouring gun metal consisting of 88 parts copper, 10 parts tin, and 2 parts zinc, at 950° C. (1,740° F.)[b], this temperature being far too low and giving a poor casting of low tensile strength, hence evidently not far above the melting point.

The figure is probably not correct, as an alloy consisting of 90 parts of copper and 10 parts of tin melts at about 1,005° C. (1,840° F.), and substituting 2 parts of zinc would probably not lower the melting point to 950° C.

Primrose [c] in a later paper presents a cooling curve for gun metal containing 88 per cent copper, 10 per cent tin, and 2 per cent zinc, with less than 0.2 per cent lead (exact analysis not given), which shows the melting point (liquidus) at 1,010° C., or slightly above that for a corresponding zinc-free bronze, although some lowering of the melting point by the zinc might be expected.

Langmuir [d] also poured some alloys at a temperature at which the metal would just flow, and so cold that in all cases the castings were poor and the tensile strength was low. The results obtained by Langmuir were as follows:

Pouring temperatures of four alloys.

Alloys.	Pouring temperatures.	
	°C.	°F.
Gun metal	965	1,770
Yellow brass	850	1,560
Red brass	1,058	1,935
Muntz metal	943	1,730

These figures, also, are probably not accurate. The remark on the earlier figure by Primrose for gun metal applies here. The composition of the alloys was not given. If it be assumed that the names were used in their normal significance, the yellow brass should have been about 65 parts copper and 35 parts zinc, an alloy

[a] Primrose, H. S., Metallography as an aid to the brass founder: Metal Ind., vol. 8, 1910, p. 466.

[b] Since the accuracy of temperature measurements at the melting points of brasses and bronzes does not warrant figuring to a degree, the results of transforming Centigrade or Fahrenheit measurements to the other scale are calculated in round numbers to the nearest 5° or 10°.

[c] Primrose, H. S., and Primrose, J. S. G., Practical heat treatment of Admiralty gun metal: Jour. Inst. Metals (British), vol. 9, 1913, p. 169.

[d] Langmuir, P., quoted by Law, E. F., Alloys and their industrial application, 1909, p. 10.

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that melts at about 915° C. (1,680° F.), and the Muntz metal should have contained 60 parts copper and 40 parts zinc, an alloy that melts at about 890° C. (1,635° F.). Muntz metal has a lower melting point than yellow brass, not higher as shown by these figures. Similarly, red brass of the common composition, which is about 85 parts copper, 5 tin, 5 zinc, and 5 lead, has a lower melting point than gun metal, taken as 88 parts copper, 10 tin, and 2 zinc.

Karr [a] used a radiation pyrometer in determining the melting points and pouring temperatures of some copper alloys. For an alloy of 68.8 parts copper, 0.2 parts lead, and 31 parts zinc he gives 1,640° F. (895° C.), a figure that is considerably lower than the true melting point, because, evidently, of the well-known deviation from black-body conditions of molten copper or its alloys. Karr gives 1,650° F. (900° C.) as the melting point of one alloy containing 84 per cent copper, 1,735° F. (945° C.) as that of another of the same copper content, and 1,850° F. (1,010° C.) as that of another said to correspond to gun metal but containing no zinc. Karr's figures are confessedly inaccurate because of the deviation from black-body conditions, and in only one case is the exact composition of the alloy given.

As the literature on the subject was found to be so meager, it was decided to determine the melting points of a few typical commercial alloys with sufficient accuracy for the purpose in hand.

METHODS USED IN THE TESTS.

The alloys were melted in a gas furnace. Instead of crucibles of the ordinary shape, which exposes too large a surface to volatilization and oxidation, the crucibles used were made from some bonded carborundum tubes that were in stock from a previous investigation.

The carborundum tubes, which are described in detail by Gillett,[b] were about 4.5 cm. inside diameter and had walls about 8 mm. thick. They were cut to about 15 cm. long and a plug of artificial graphite was fitted at one end to form the bottom and luted in place with alundum cement. Considering the cost of machining out a crucible from a graphite rod, as well as that of the graphite itself, these crucibles were much cheaper than those of artificial graphite, especially as they burned away much more slowly than graphite. Their life was as long as that of the ordinary crucibles made of fire clay and graphite.

The temperatures were measured by a platinum, platinum-rhodium thermocouple used with a single-pivot galvanometer. The couple was calibrated against one that had been checked against one cali-

[a] Karr, C. P., The pouring and melting points of some high-grade bronzes: Trans. Am. Brass Founders' Assn., vol. 5, 1911, p. 78.

[b] Gillett, H. W., Temperature measurements in an experimental carborundum furnace: Jour. Phys. Chem., vol. 15, 1911, pp. 225, 227.

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brated by the Bureau of Standards, the secondary standard having been read on a potentiometer and its scale found to be correct within the limits of error of reading. The calibration was also checked by reading the melting points of copper, of common salt, and of a bronze consisting of 90 parts copper and 10 parts tin. At these points the scale was correct within the error of reading.

As these calibrations were made with the cold junction at 20° C., the couple was used without placing the cold junction in ice water, the cold junction being so protected from the furnace that the readings of a thermometer at the cold junction did not vary 3° from 20° C. during all the runs.

The thermocouple wires were insulated by Marquardt tubing of 1 mm. bore and 2 mm. outside diameter, and the hot junction was slipped into a Marquardt tube 30 cm. long, of 9 mm. outside diameter and 5 mm. inside diameter, that was closed at one end. The open end of this tube was fastened, with alundum cement, into an open-ended porcelain tube 35 cm. long, and of 10 mm. inside diameter and 14 mm. outside diameter. This arrangement served to protect the couple from zinc fumes or reducing gases. The end of the protecting tube was in turn protected from the molten metal by an artificial graphite boot 9 cm. long, with walls 3 mm. thick.

There is a considerable time lag in a pyrometer reading when a cold protecting tube and boot are plunged into molten metal, but after the tube is once hot the lag is small. As the melting points were not determined by noting when the metal solidified, but by plotting temperatures against time, the proper temperatures for the heat evolution on freezing or heat absorption on melting should be shown even if there was some lag.

About 600 grams of metal was used in making the tests. The metals were weighed in the proper proportions to form the alloy desired, a slight excess of zinc, increased with increasing zinc content, being allowed to compensate for volatilization. Electrolytic copper, Bertha zinc, and chemically pure lead and tin were used. The copper was melted first, and then covered with granular carbon and a little salt. When the copper was melted the tin, the lead, and lastly the zinc were added, and the alloy was well stirred with a graphite rod.

When the alloy was fully melted and mixed the pyrometer was inserted and so clamped that the graphite boot did not touch the bottom or sides of the crucible. The gas flame was lowered and the temperature read every 15 seconds, the melt being stirred between each reading. When the alloy had frozen, the gas was turned up and a heating curve was taken. This procedure was repeated several times. Zinc was continually volatilized from the melts containing zinc, but not in sufficient quantity to have appreciable effect on the

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melting point, as duplicate runs agreed within 5° C. in all cases. After a run was completed, the melt was usually poured into an ingot mold, sampled, and analyzed. As the analyses of the samples analyzed agreed well with the composition desired, the melts containing zinc were not analyzed. Duplicate analyses of the same sample agreed within 0.1 per cent.

All the melts were made from virgin metals except a sample of manganese bronze which was in the form of test-bar ends from a previous investigation.[a] It had shown a tensile strength of 76,000 to 77,000 pounds per square inch and an elongation of 24 to 35 per cent in the standard brick-form test bar. The bronze had approximately the following composition: Copper, 56 per cent; zinc, 41 per

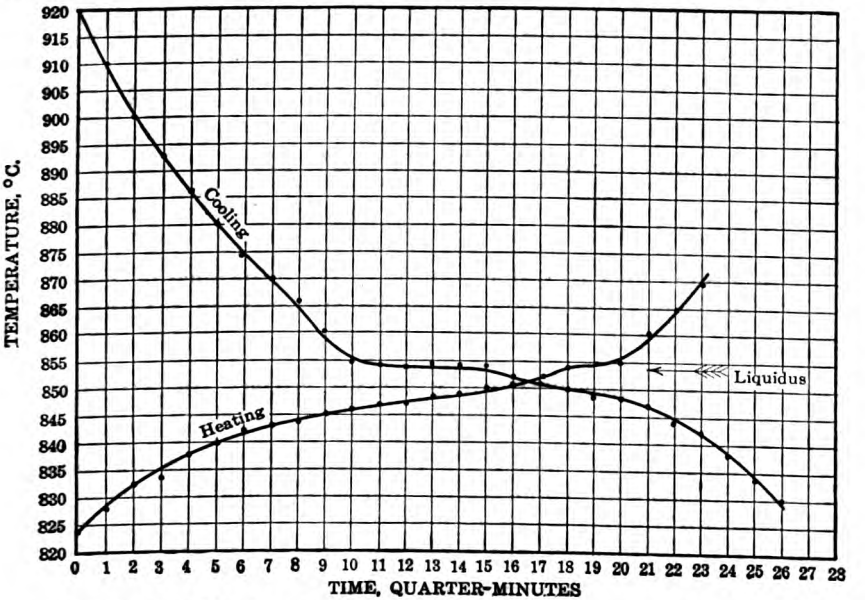

FIGURE 1.—Freezing and heating curves of naval brass made of 61.7 parts copper, 36.9 parts zinc, and 1.4 parts tin.

cent; iron, 1.5 per cent; tin, 0.9 per cent; aluminum, 0.45 per cent; and manganese, 0.15 per cent.

As the bronze was first cast into an ingot, then remelted and cast into test bars, and these again remelted for melting-point determination, the zinc content was probably nearer 40 than 41 per cent and the copper content nearer 57 than 56 per cent when the melting points were taken. This sample was not analyzed.

The melting point given is the liquidus, or point at which freezing begins on cooling and liquefaction ends on heating. This is more strongly marked than the solidus, or point at which freezing ends on cooling and liquefaction begins on heating. Figure 1 shows one set

[a] Gillett, H. W., The influence of pouring temperature on manganese bronze: Trans. Am. Inst. Metals, 1912, page 207.

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of curves and the characteristic break at the melting point (liquidus). These curves are typical of all melting-point determinations.

RESULTS OF TESTS.

The data obtained in the determination of the melting points of several alloys were as follows: [a]

Melting-point determinations for 10 alloys.

Alloy.	Composition desired.				Composition by analysis.				Number of duplicate determinations.	Melting point (liquidus).	
	Cu.	Zn.	Sn.	Pb.	Cu.	Zn.	Sn.	Pb.			
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*		°*C.*	°*F.*
Gun metal	88	2	10	.....	.....	.....	.....	.....	4	995	1,825
Leaded gun metal	85½	2	9½	3	85.4	1.9	9.7	3.0	6	980	1,795
Red brass	85	5	5	5	.....	.....	.....	.....	[1] 8	970	1,780
Low-grade red brass	82	10	3	5	81.5	10.4	3.1	5.0	4	980	1,795
Leaded bronze	80	.....	10	10	.....	.....	.....	.....	3	945	1,735
Bronze with zinc	85	5	10	.....	84.6	5.0	10.4	.....	4	980	1,795
Half yellow, half red	75	20	2	3	75.0	20.0	2.0	3.0	3	920	1,690
Cast yellow brass	67	31	.....	2	66.9	30.8	.....	2.3	4	895	1,645
Naval brass	61½	37	1½	.....	61.7	36.9	1.4	.....	5	855	1,570
Manganese bronze	.....	.....	.....	.....	.....	.....	.....	.....	6	870	1,600

[1] 2 samples.

As the results all checked within 5° C., an allowance of ±10° C. or ±20° F. is probably ample to cover all errors in reading, calibrating, and using the pyrometer.

PREVIOUSLY DETERMINED MELTING POINTS OF BINARY ALLOYS.

For comparison, the melting-point (liquidus) figures for binary systems of copper-tin,[b] copper-zinc,[c] and copper-lead [d] alloys for the range covering the common industrial alloys are given below. These are scaled from curves in the references given. As the curves are small, the figures are only accurate to within about ±10° C. or ±20° F.

[a] The melting points and analyses were obtained by A. B. Norton, with aid from S. J. Popoff, at Cornell University, under the direction of Prof. W. D. Bancroft, of Cornell University, and of H. W. Gillett, of the Bureau of Mines.

[b] Shepherd, E. S., and Upton, G. B., Tensile strength of copper-tin alloys: Jour. Phys. Chem., vol. 9, 1905, p. 446.

[c] Shepherd, E. S., The constitution of the copper-zinc alloys: Jour. Phys. Chem., vol. 8, 1904, p. 423.

[d] Desch, C. H., Metallography (Copper-lead alloys), 1910, p. 85.

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Melting points of binary alloys.

COPPER-TIN ALLOYS.

Parts by weight.		Melting point.	
Copper.	*Tin.*	*° C.*	*° F.*
95	5	1,050	1,920
90	10	1,005	1,840
85	15	960	1,760
80	20	890	1,635

COPPER-ZINC ALLOYS.

Copper.	*Zinc.*	*° C.*	*° F.*
95	5	1,070	1,960
90	10	1,055	1,930
85	15	1,025	1,880
80	20	1,000	1,830
75	25	980	1,795
70	30	940	1,725
65	35	915	1,660
60	40	890	1,635

COPPER-LEAD ALLOYS.

Copper.	*Lead.*	*° C.*	*° F.*
95	5	1,065	1,950
90	10	1,050	1,920
85	15	1,035	1,895

Although the melting points of only 11 alloys were determined, the alloys chosen represent a large proportion of the nonferrous alloys in use in the ordinary foundry. The composition of many of the other common alloys is near enough to these or to the binary alloys whose melting points are given to allow the melting point being obtained by interpolation closely enough for most technical purposes.

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PUBLICATIONS ON MINERAL TECHNOLOGY.

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BULLETIN 47. Notes on mineral wastes, by C. L. Parsons. 1912. 44 pp.

BULLETIN 53. Mining and treatment of feldspar and kaolin in the southern Appalachian region, by A. S. Watts. 1913. 170 pp., 16 pls., 12 figs.

BULLETIN 64. The titaniferous iron ores in the United States; their composition and economic value, by Joseph T. Singewald, jr. 1913. 145 pp., 16 pls., 3 figs.

BULLETIN 71. Fuller's earth, by C. L. Parsons. 1913. 34 pp.

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